SECTION V

RECREATIONAL IMPORTANCE OF LAKE

A. HISTORY

Originally, Lake Hopatcong consisted of two bodies of water, Huppakong Lake and Woodport Pond, joined by a small stream. The first permanent inhabitants of Lake Hopatcong were the Neticong Indians. They maintained a sizeable settlement along the shores of Huppakong Lake. The Indians were driven out in the early 1700's by settlers lured to the lake area by the discovery of rich iron ore deposits in the surrounding hills. These deposits, the ample supply of wood for fuel, and the availability of a source of water power resulted by the mid-1700's in the establishment of an iron forge in the lake area. In 1750, a 5 foot dam was built at the outflow on the south shore of the lake for the purpose of obtaining water power for the forge and a saw mill. The forge was very active during the Revolutionary War, but due to lack of easily accessable wood fuel, became inoperative in 1829.

In the 1820's, the demand for Pennsylvania coal in the metropolitan New York City area led to the construction of the Morris Canal. In 1827, a new dam was built at the outlet of the lake to help supply water for the canal. The lake was raised an additional 6 feet, substantially increasing its original size. The lowlands between Huppakong Lake and Woodport Pond were inundated, resulting in the formation of one large lake. The Morris Canal was active from 1827 to the end of the Civil War, when at that time it could no longer compete with the rapidly developing railroads.

Although the railroads made the canal obsolete, they stimulated the resort industry of Lake Hopatcong. By rail, New York City was only two hours away. Many wealthy urban dwellers vacationed or maintained seasonal residences at the lake. Resort hotels, inns and summer cottages were constructed to accommodate the many summer tourists who visited Lake Hopatcong.

Between 1880 and 1920, numerous resort hotels, summer cottages and permanent homes were built, and Lake Hopatcong became recognized as a major tourist center. In 1920, the State of New Jersey assumed the rights to the waters of Lake Hopatcong, preserving the lake for recreation use, and in 1925 replaced the old Morris Canal dam with a new structure.

The era of greatest growth at Lake Hopatcong occurred after World War II, with the construction of many summer residences. By 1960, a trend toward year around residential developments became apparent, and presently most residences on the lake and in the watershed are year-round permanent homes. Recreational use by non-residents is still high, particularly on weekends. Access is generally gained to the lake by tourists at Lake Hopatcong State Park. The use by one-day and weekend visitors has reportedly decreased by 35% over the period from 1964 to 1974. In 1964, 145,000 visitors were counted at the State Park, but in 1975, the number was down to 95,000 (Levin and Moskowitz, 1977). The recent gasoline crises have resulted in a resurgence of Lake Hopatcong's popularity. The recreational use of Lake Hopatcong remains relatively high, and will continue due to the lake's proximity to the metropolitan New New York-New Jersey area and its recreational attributes.

B. LAKE USES

Lake Hopatcong is of vital economic, recreational, and aesthetic importance to the lakeland region. It provides water-based recreation for a large resident and tourist populus. The lake is also an intrinsic part of the region's economic base. It was assumed that with the development of the Delaware Water Gap National Recreation area, some of the existing recreational demand placed on the lake would decrease. However, with the postponement of the Tock's Island Dam, or its possible de-authorization, there will not be an alternate large-multi-use water body as had originally been planned. Because of the increasing cost of transportation, Lake Hopatcong should remain an important recreational resource due to its proximity to the metropolitan New York-New Jersey area. However, extensive recreational use of the lake will be highly dependent on the maintenance of reasonably good water quality.

Survey results indicate that the majority of people utilizing the lake are day visitors who reside in the Northeastern New Jersey-New York City area (LHRPB 1977). Most day visitors utilize the public facilities available at the State Park. Swimming is the most important activity for visiting lake users followed by boating, picknicking, and fishing (Table 15).

The demand placed on Lake Hopatcong in relation to boating is of prime consideration. Power boating, particularly outboard, generates noise and petroleum pollution. It is also readily affected by the establishment of dense aquatic macrophyte beds which tangle props and impede travel. The number of boats operating in the lake is estimated to be 400 on an average weekend day and 600-800 on a peak weekend day. Based on State Recreation Plan Standards, Lake Hopatcong should be able to accommodate as many as 900 boats at one time. The average boat operating in Lake Hopatcong, is 16 ft in length, powered by an 80 HP outboard motor, and owned by a male 25.8 years of age (Table 16). Most

TABLE 15

RECREATIONAL USE OF LAKE HOPATCONG

Activity	Recreation Days Per Year		Percent of People Listing Activity	
	Number	Percent	State Park	Lake
Swimming	73,500	64.8	90	90
Fishing	20,500	18.1	(a)	44
Boating	15,100	13.1	47 (b)	60
Water Skiing	3,100	2.7	(a)	38
Sailing	1,300	1.1	(a)	9
Picknicking	(a)		60	50
Amusement Park	(a)		22	17

(a) Not mentioned.

(b) Until 1976, a small excursion boat ran from the State Park and was popular with Park visitors (LHRPB 1977).

Each of these recreational activities are treated in the text in more detail.

From: Levin, M.R. and M.S. Moskowitz. 1977. Planing for an Inland Lake: Alternatives for Lake Hopatcong. Lake Hopatcong Regional Planning Board.

Table 16

SUMMARY OF MOTOR BOAT DATA

	Outboard	Inboard	Out/Inboard	Total
Average Horsepower	60.2	166.1	160.6	80.0
Mean Length (ft)	15.4	18.7	18.0	16.0
Hull Material				
Fiberglass	70.8%	38.7%	97.7%	73.3
Wood	14.4%	58.1%	-	14.6
Aluminum	13.6%	3.2%	2.4%	11.2
Steel	1.0%	-	-	0.7
Rubber	0.2%	-	-	0.2
Sex of Operator	91% male	89% male	*	91% male
Average Age of Operator	25.35 yrs	26.48 yrs	27.75 yrs	25.81 yrs
$\bar{X}$ Number of Persons on Board	3.01	3.53	3.27	3.10

* Inboard & Outboard combined.

From: Levin, M.R. and H.S. Moskowitz 1977. Planning for an inland lake: Alternatives for Lake Hopatcong. Lake Hopatcong Regional Planning Board.

boat operators also tend to be day visitors rather than local residents, this being particularly true on weekends.

Related to power boating is water skiing, and in Lake Hopatcong the majority of such activity occurs in Woodport Bay, King Cove, Byram Cove and in the vicinity of Halsey Island. At times, the density of boat traffic is so great that it interferes with water skiing activities.

Sailing is increasing in popularity at Lake Hopatcong. Some marinas offer sailboat rentals, as well as docking facilities. Canoeing, however, generates only minor activity on the lake. The attractiveness of the lake to canoeing is largely diminished by the intensive use of motor boats and their resulting wakes.

Lake Hopatcong is also the host for an annual hydroplane regatta. The race, which draws competitors from throughout the country, is held in early September.

The Hopatcong State Park beach is used very heavily by day visitors as it is the only non-commercial swimming facility. Additional facilities are provided by community beaches. Based on a survey conducted at the State Park (LHRPB, 1977), the average weekday visitor to the State Park is white, female, and travelled approximately 32 miles by car to use the lake. Typically weekday visitors are mothers and children who come to the park for a brief (4.0 hrs) stay. The average weekend user is black or Puerto Rican, male, and travelled 43 miles by car. Of the weekday users 43% live in the metropolitan New York-New Jersey region and 40% live in Morris and Sussex Counties, whereas of the weekend users, 78.5% are from the New York-New Jersey metropolitan area and only 6% live in

Morris or Sussex Counties. Thus the lake, and in particular the State Park, appears to provide an important weekend recreational site for urban residents.

For seasonal and year-round residents, swimming facilities are available in the form of lake association and private club beaches, town beaches, and private beaches (Levins and Moskowitz, 1977).

On the basis of existing data, and following the standard prescribed by the NJ State Outdoor Recreation Plan, it is felt that the swimming facilities presently available at Lake Hopatcong easily meet user demands (LHRPB, 1977).

Fishing is another popular activity for lake residents and day visitors. Bertrand Point, Nolan's Point, and Elba Point are the three more heavily fished areas of Lake Hopatcong. Panfish, bass, perch, and pickerel, are the most commonly landed fish. The lake has been stocked at times with walleye, and annually with trout.

Ice boating and ice fishing are the two major winter sports provided by the lake. When weather and ice conditions are favorable, the long narrow nature of the lake's main basin makes it highly suitable for ice boating. Most ice boating takes place in the Great Cove section of the lake. Ice fishing is very popular, with as many as 300 fishermen utilizing the lake on weekends. An annual ice fishing derby, sponsored by the Knee-Deep Hunting and Fishing Club of Lake Hopatcong, has attracted over 1000 fishermen.

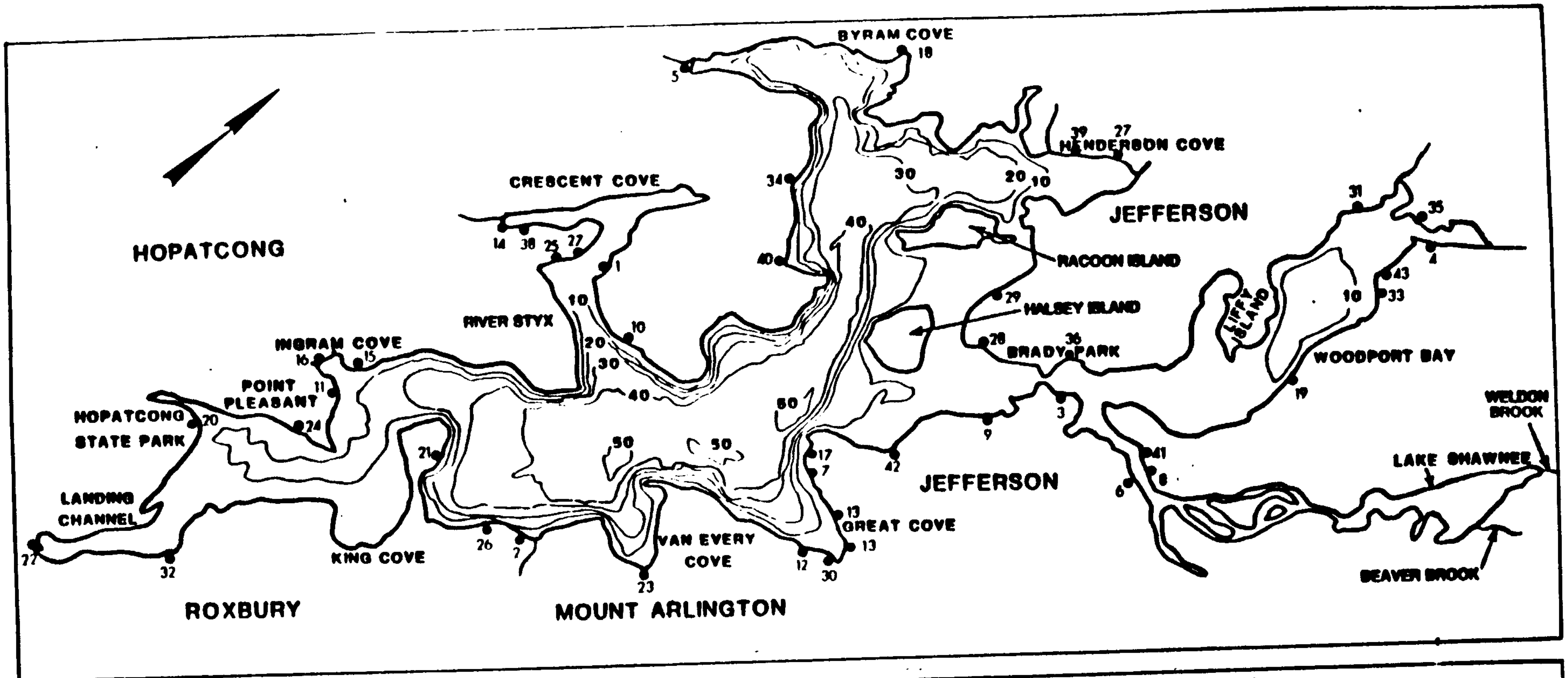
C. PUBLIC ACCESS TO THE LAKE

Public access to Lake Hopatcong for recreational purposes is not a problem since it is a state-owned lake. For year-round and seasonal residents there are a number of access points to the lake for swimming. These include private beaches, municipal beaches, commercial beaches, and Lake Hopatcong State Park which is the most important public access point. The state park has a large public swimming beach and boat launching area. It is the sole access point for "day trippers" who wish only to swim. There are 39 marina and docking facilities, of which 22 are commercial marinas equipped with launching areas and dock space (Table 17, Figure 3).

Table 17

LAKE HOPATCONG MARINAS AND LAUNCHING FACILITIES

Marina	Index No.	Private Facility	Club Facility	No. Rental Slips	Launching Ramp	Hoist	Winter Storage	Repairs	Fuel	Swimming Facilities
Arrowcrest	1	x		10						
Barnes Bros.	2	x		65	x	x	x	x	x	
Bridge Marine	3	x		152	x			x	x	x
Brights Marine	4	x		60	x					
Byram Cove Club	5		x	8	x					x
Chabon's	6	x		165	x					x
Dick Dowd's	7	x		5	x					
Dunn's Triangle	8	x		80	x					
East Shore Estates	9		x	20	x					x
Elba Point	10		x	25	x					x
Garden State Yacht Club	11		x	30	x					x
Great Cove Park	12	x		100	x	x				x
Hockenjos	13	x		30	x	x	x	x	x	
Hopatcong Hills	14		x	35	x					x
Ingram Cove Club	16		x	10	x					x
Jefferson House	17	x		15						
Knollwood Club	18		x	10	x					x
Lake Forest	19		x	85	s					x
L.H. State Park	20	State Park		0	x					x
L.H. Yacht Club	21		x	100	x	x				
Lakes End Marina	22	x		20	x			x	x	
Lee's Park	23	x		65	x		x	x	x	
Logan Hills	24		x	10	x					x
Light House	25	x		45						
Mt. Arlington Beach	26		x	5						x
Northwood Inn	27			10						x
Prospect Point	28	x		15	x	x	x	x	x	
Prospect Point Club	29		x	3	x					x
Sand Bat	30	x		100		x	x	x		x
Seyman's Cellar Bat	31	x		12						
Shore Hills Club	32		x	50	x					x
Smitty's Marina	33	x		90		x	x	x	x	
Sperry Spring	34		x	15						x
Sportsman Cove	35	x		10						
Tiny's Bar	36	x		24	x					
Traps Marine	37	x		85	x		x	x		
Village Marine	38	x		40	x			x	x	
Wayne's Marine	39	x		30	x	x	x	x	x	
Wildwood Shoes Club	40		x	15						x
Willomay Park	41	x		25						
Windlass	42	x		40						
Woodport Boat Basin	43	x		265	x	x	x	x	x	x



LEGEND

● 20 CONSULT TABLE 17 FOR NAME OF FACILITY

FEET
0 1000 2000

0 200 400
METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 3

PUBLIC ACCESS POINTS, MARINAS, & LAUNCHING FACILITIES, ON LAKE HOPATCONG

pa=

D. COMPARISON TO OTHER LAKES IN NORTHERN NEW JERSEY IN TERMS OF RECREATIONAL POTENTIAL AND USAGE

There are approximately 8 major public lakes or reservoirs, within an 80 km radius of Lake Hopatcong, which provide a recreational outlet for central New Jersey and NY-NJ metropolitan area residents (Table 18). The water quality of Lake Hopatcong is comparable, if not better than most of the other lakes, but poorer than that of Spruce Run, Wanaque, and Round Valley Reservoirs (USEPA, 1978). However, the recreational demand placed on Lake Hopatcong far exceeds that placed on the other lakes and reservoirs. This is due to a combination of the lake's proximity to major cities, the availability of public access points, its large size, and recreational outlets.

Table 18

COMPARISON OF MAJOR WATER BODIES IN THE VICINITY OF LAKE HOPATCONG

Water Body	County	Area km^2	Public Access	Available Recreation	Trophic State
Spruce Run Res.	Hunterdon, NJ	5.22	yes	a,b,d,f,g,h	eutrophic
Round Valley Res.	Hunterdon, NJ	9.51	yes	a,b,d,f,g,h	mesotrophic
Paulinskill Lake	Sussex, NJ	0.64	yes	a,b,c,d,e,f,g,h	eutrophic
Swartswood Lake	Sussex, NJ	2.00	yes	a,b,c,d,e,f,g,h	eutrophic
Wawayanda Lake	Sussex, NJ	1.03	yes	a,b,d,f,h	mesotrophic
Greenwood Lake	Passaic, NJ/ Orange, NY	7.77	yes	a,b,c,d,e,f,g,h	eutrophic
Pompton Lake	Passaic	0.83	yes	a,b,c,f,h	eutrophic
Wanaque Res.	Passaic	9.35	no	no recreational activities allowed	mesotrophic
Budd Lake	Morris, NJ	1.52	yes	a,b,c,d,g,h	eutrophic
Lake Musconetcong	Sussex, NJ/ Morris, NJ	1.33	yes	a,b,c,d,f,g,h	eutrophic
Lake Shawnee	Morris, NJ	0.20	no	a,b,d,f,g	eutrophic

a - fishing; b-swimming; c-boating, motor; d - boating, sail/electric motor; e - waterskiing; f - picnicking, camping; g - winter activities; h - miscellaneous.

SECTION VI

WATER QUALITY MONITORING PROGRAM

A. INTRODUCTION

In order to establish the existing conditions of the lake and its tributaries, ascertain historical trends in the degradation of the lake's water quality, and identify the interrelationships among the physical-chemical-biological components of Lake Hopatcong, a detailed water quality monitoring program was conducted. The goal of this program was to identify the problems of Lake Hopatcong and develop, from this data, an effective restoration action plan. The methodologies utilized in this study were designed to generate data which would provide a sound framework for the selection of appropriate restorative and management techniques. In this manner, the problems and features unique to Lake Hopatcong and its surrounding watershed will be properly addressed.

B. STATION SELECTION AND LOCATION

A total of 6 in-lake stations and 8 tributary stations were monitored on a regular basis (Table 19, Figure 4). The lake stations were monitored bi-weekly from April through September, and monthly the remaining months. The tributary stations were monitored on a monthly basis year-round. Additional stations were selected and monitored on a more infrequent basis for storm contributions, sediment composition, surveys of the fish, benthos, and macrophytes, and septic and sewage contributions. The location and frequency of these sampling programs will be addressed in those sections and sub-sections of this report which address these areas in more detail.

Table 19

IN-LAKE AND STREAM SAMPLING STATIONS

Designation	Location
Stream Stations:	
LHS 1	Lake Shawnee Dam overflow
LHS 2	Outfall from Weldon Brook into Lake Shawnee
LHS 3	Outfall from Lake Wenona into Lake Hopatcong
LHS 4	Stream under Prospect Point Road at north end of Woodport Bay
LHS 5	Jayne Brook at Lakeside Avenue
LHS 6	Stream under Maxim Drive that flows into southwest end of Byram Cove
LHS 7	Stream under Crescent Road with storm sewers that flow into southwest corner of Crescent Cove
LHS 8	Stream at foot of Altenbrand Road
Lake Stations:	
LH 1	Woodport Bay
LH 2	Main basin, off Chestnut Point
LH 3	Point Pleasant
LH 4	In vicinity of spillway near Hopatcong State Park
LH 5	Center of Crescent Cove
LH 6	Southwest side of Halsey Island

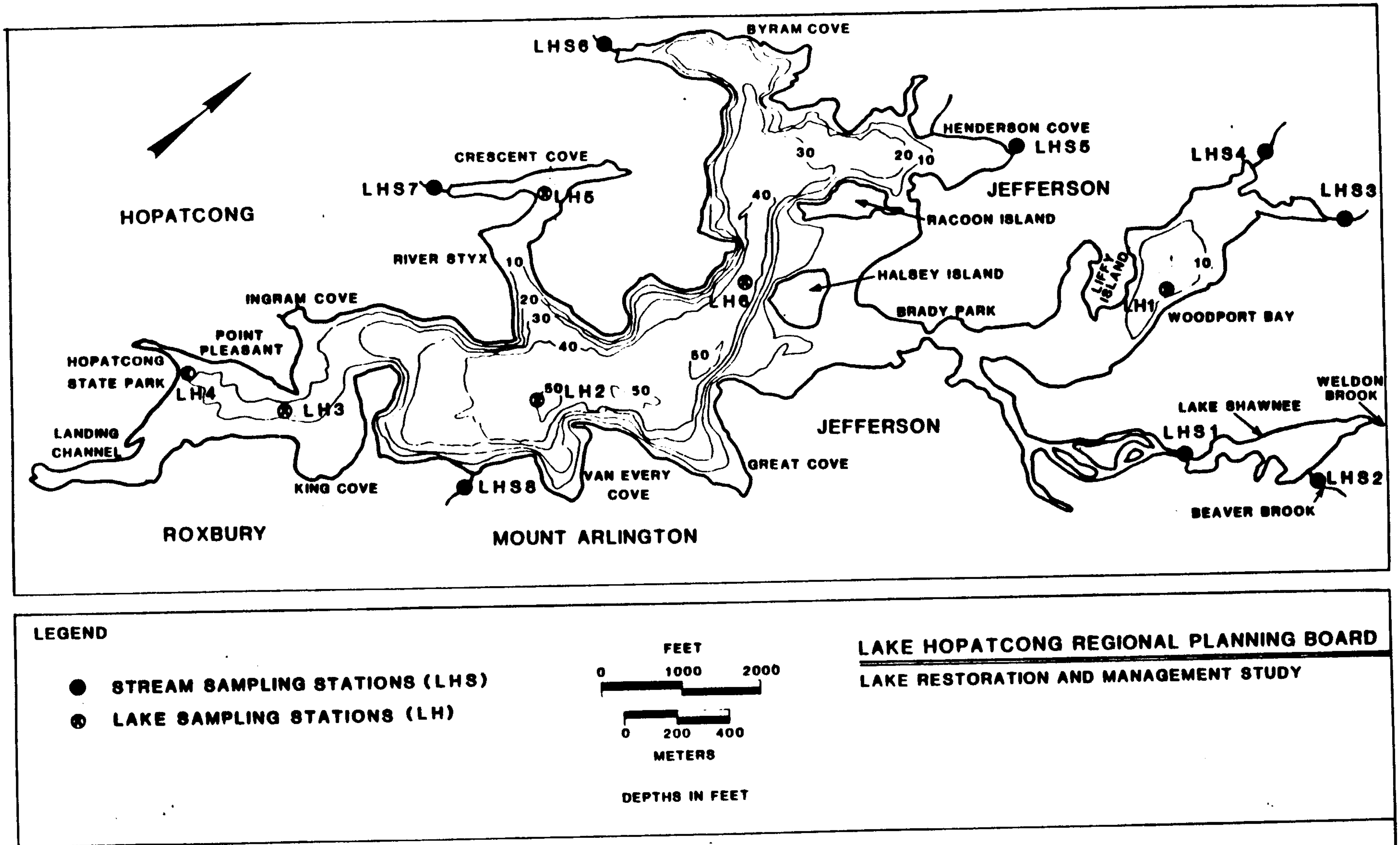


FIGURE 4

LAKE AND STREAM SAMPLING STATIONS

C. METHODS AND MATERIALS

1. In-Lake Sampling Program

A non-metallic Kemmerer sampling bottle was used to collect in-lake water samples. The water column at lake stations LH1, LH3, and LH6 was sampled 0.5m below the surface, and 0.5m above the bottom. Lake Station LH2, the deepest spot in the lake, was sampled at six depths; 0.5m, 3.0m, 6.0m, 9.0m, 12.0m, and 0.5m above the bottom. Samples were collected from only one depth, halfway between surface and bottom, at the shallow lake stations LH5 and LH4.

Water quality samples were collected, preserved, and transported to PAS laboratory facilities for analysis following EPA accepted methods. Quality control was in keeping with the guidelines developed by the State of New Jersey as detailed in the Quality Control Assurance Plan for the PAS Laboratory (PAS, 1982).

In situ measurements of air temperature, wind speed and direction, surface water temperature, and Secchi disc transparency were recorded for each sampling station. The temperature/dissolved oxygen profile at each station was measured using a Rexnord portable temperature/ dissolved oxygen probe. The pH of each sample was determined immediately upon collection.

Water samples to be analysed by the PAS laboratory, were dispensed from the Kemmerer sampling bottle into polyethylene containers. Four 1 liter samples were obtained at each sampling depth for each lake station. One was preserved with sulfuric acid, another with Lugol's solution, and the remaining two left unpreserved. From each of the appropriately preserved bottles, the following parameters were analysed as per

Standard Methods for the Examination of Water and Wastewater 14th ed. (1975), and in accordance with 40 CFR 136 et. seq.

Preserved with sulfuric acid

- total kjeldahl nitrogen
- nitrate and nitrite-nitrogen
- ammonia nitrogen
- total nitrogen
- total phosphate-phosphorus

Preserved with Lugol's solution

- whole phytoplankton

No preservative

- chlorophyll a, b, and c; phaeophyton (1 liter)
- orthophosphate-phosphorus
- suspended solids
- turbidity
- alkalinity
- specific conductance
- hardness
- pH

Net phytoplankton and zooplankton were also collected at each station on each sampling date except during ice cover. A 60 micron net was used to collect phytoplankton and a 153 micron net was used to collect zooplankton. Both nets were towed obliquely, at an approximate depth of 0.5 meters, for a set duration (usually 1 minute), and a set speed (usually 0.5 knots). Samples were transferred to 10 ml vials. The 60 u net sample was preserved with a formalin-copper sulfate solution whereas the 153 u net sample was preserved with a buffered formalin-rosebengal solution. Phytoplankton were identified to genus.

In addition to the above routine analyses, periodic sampling of the benthos, aquatic plants, fish, and sewage/septage related bacteria were conducted.

Benthic samples were collected using a 229 mm x 229 mm x 229 mm Ekman dredge. Bottom samples were sifted through 2000 mm and 1000 mm screens, the retained organisms picked, transferred to 10 ml vials, and preserved with a formalin-rosebengal solution. In the laboratory, organisms were identified to the lowest possible taxa following the criteria of Pennak (1978), Ward and Whipple (1966), and Merritt and Cummins (1978).

A survey of the lake's fishery was conducted using haul seine equipment. Species were identified in the field, and their weight, length, sex, and total numbers recorded.

A combination of SCUBA and surface techniques were employed to determine the extent, density, and species composition of the aquatic macrophytes of Lake Hopatcong. Transects were established from which samples were collected and semi-quantitative observations made. At a number of sites, all plants within a 1000 cm^2 quadrant were harvested. Upon return to the laboratory, the plant material was washed, sorted, and identified to species. The wet weight, ash weight, and organic content were determined. In addition, the concentration of total phosphorus, total kjeldahl nitrogen, and metals of a few sub-samples were measured. The chemical and biological methodologies recommended in Standard Methods for the Examination of Water and Wastewater, 14th ed. (1975), and Weber (1973) were followed.

2. Stream Sampling Program

Monthly surface grab water samples were collected from mid-channel at each of the stream stations. A total of eight tributary stations were sampled. The location of each station is noted on Figure 4, and listed in Table 19.

Future reference to these stations will be made using the LHS nomenclature.

Samples were collected in two 1 liter polyethylene containers. One container was preserved with sulfuric acid, and the other left unpreserved. Samples were stored on ice and transported to PAS laboratory facilities for analysis. From the appropriately fixed containers, the following parameters were analysed:

Preserved with sulfuric acid

- total kjeldahl nitrogen
- nitrite and nitrate-nitrogen
- ammonia nitrogen
- total nitrogen
- total phosphate-phosphorus

Non-preserved

- orthophosphate-phosphorus
- suspended solids
- turbidity
- specific conductance
- alkalinity
- hardness

In-situ measurements of pH, air and water temperature, and windspeed and direction were recorded, and general meteorological conditions noted.

Precipitation in the watershed was measured and recorded by a LHRPB volunteer. Precipitation records maintained by the National Oceanic Atmospheric Administration (NOAA) for the Lake Hopatcong area were used as a means of verifying their accuracy.

3. Point Source Sampling Program

There are four sewage treatment plants (STPs) located within the watershed of Lake Hopatcong which discharge to the lake's tributaries. Each point source discharge was identified by name, location, New Jersey Pollution Discharge Elimination System (NJPDES) permit number, receiving stream, and maximum allowable flow.

Physical, chemical and biological parameters were monitored at each point source. Samples were collected by means of grab and automated samplers, and composited over peak four-hour flow (10:00 to 14:00). The following parameters were analysed:

- BOD_5
- Suspended Solids
- pH (in situ)
- Fecal coliform
- Temperature
- Total organic carbon
- Total phosphorus

Orthophosphate-phosphorus
Total kjeldahl nitrogen
Nitrite and nitrate-nitrogen
Ammonia nitrogen

Peak four hour flow composite data were evaluated with respect to loading of nutrients, sediment, organics and biochemical oxygen demand. Data were compared and evaluated relative to the National Eutrophication Survey data, NJPDES data, and existing permits for the point sources.

4. Evaluation of Septic Contributions

Nutrient contributions associated with improperly operating on site waste disposal systems were assessed. Although such nutrient loads were ultimately quantified using the methodology outlined in NES Working Paper #175 (USEPA, 1976), various survey techniques were employed to determine the potential number of failing septic systems in the immediate (100-200 m) proximity of the lake's shoreline.

Potentially failing systems were located by means of aerial infrared photography and the use of portable fluorescence-conductivity meter, commonly called a "septic snooper".

The infrared aerial photographs of the lake basin were taken by EPA personnel using a wing-strut mounted enviropod camera. The photographs were shot in March 1982 at an altitude of 350 meters (1,000 ft).

An in-lake survey of possible septic plumes was conducted using the "septic snooper". With the septic snooper mounted in a small boat and the sampling probe lowered overboard and submerged 0.5 m, a continuous scan of fluorescence and conductivity was obtained as the boat motored slowly around the lake's perimeter. Background fluorescence and conductivity were factored through calibration of the unit at a deep water mid-lake station. Full details regarding the calibration and use of the unit are presented in the "ENDECO Type 2100 Septic Leachate Detector System Operators Manual" (Kerfoot, 1980).

D. TROPHIC STATE ANALYSIS

Emphasis was placed on the role of phosphorus in determining the productivity of Lake Hopatcong. For most temperate lakes, phosphorus is found to be the element which limits the amount of primary production, as represented by algae or aquatic plant growth. The importance of phosphorus stems from its low availability in the water column relative to the phosphorus requirements of algae and aquatic plants in photosynthesis and subsequent tissue production. As a result, phosphorus is usually depleted from the lake before other nutrients and thus becomes the factor that limits primary production.

A number of models have been developed which empirically calculate the trophic state of a water body on the basis of a few key parameters. The more commonly used models are reviewed by Reckhow (1979) in regard to their derivation, strength, shortcomings, and potential bias. In general, using annual TP loading, hydrologic, and morphometric data the spring total phosphorus concentration of a lake can be fairly accurately predicted. This information is important in that it provides an estimate of the amount of TP available for utilization by primary producers at the onset of the growing season. This is a determining factor of summer productivity in most lakes.

The Dillon (1974) model is one of the more popular and accurate models (Equation 1).

Equation 1: $$[P_s] = \frac{L\ (1-R)T}{\bar{Z}}$$

Where: $[P_s]$ = Spring total phosphorus concentration (gm^{-3})

L = Areal Load ($gm^{-2}yr^{-1}$)=annual TP load/lake surface area

Z = Mean depth (m)

T = Hydraulic retention (yr)

R = Phoshorus retention

Developed primarily for use with phosphorus-poor Canadian Shield lakes, it has been verified for use with north temperate, nutrient enriched lakes (Reckhow, 1977). Although a robust model, it may underestimate spring total phosphorus in highly enriched lakes, and overestimate spring total phosphorus in lakes with a large areal water load (ratio of lake outflow:lake surface area). Neither of these cases apply to Lake Hopatcong.

The phosphorus retention coefficient, R, of equation 1, is an important part of the model. It can be calculated on the basis of hydrologic data using a number of empirical models. In lakes which flush infrequently, as is the case for Lake Hopatcong, a model developed by Ostrofsky (1978) provides an accurate prediction of phosphorus retention. That model (equation 2) was used in this study to calculate R.

Equation 2: $$Rp = 0.201e^{(-0.0425qs)} + 0.5743e^{(-0.00949qs)}$$

Where: Rp = Phosphorus retention

qs = Areal water load = $\dfrac{\text{Annual Outflow from Lake}}{\text{Surface Area of Lake}}$

e = Exponential of natural log e= 2.718

The spring total phosphorus concentration generated by Equation 1, was plotted on a trophic status graph developed by Dillon (1974) for use in conjunction with that model. The graph is provided with acceptable and dangerous loading levels. By plotting L(1-R)T vs. Z, an estimate of the lake's trophic status is obtained. This procedure was carried out for existing lake conditions using TP loading data calculated from unit areal phosphorus loading computations.

The calculated spring total phosphorus concentration of Lake Hopatcong is more meaningful when assessed in terms of lake productivity. That is, how much in-lake productivity, in the form of algae or aquatic macrophyte biomass, can be expected given a certain amount of phosphorus. The chlorophyll a model of Dillon and Rigler (1974) was used in this study (Equation 3).

Equation 3: $$\log_{10}[Chla_s] = 1.449 \log_{10} [Psp] - 1.136$$

Where: $[Chla_s]$ = Summer chlorophyll a ($mg\ m^{-3}$)
$[P_{sp}]$ = Spring total phosphorus ($mg\ m^{-3}$)

The model was developed for use in lakes which have nitrogen:phosphorus ratios greater than 12:1 (potentially phosphorus limited). Such is the case for Lake Hopatcong where spring and summer nitrogen:phosphorus ratios are often >12:1 (USEPA, 1976).

It should be noted that the final predicted maximium chlorophyll a concentration is really a measure of potential primary production and general lake conditions. Other factors that affect primary production such as shading or competition for nutrients by macrophytes and benthic algae mats are not accounted for in the model. Thus, one expects discrepancies between actual measured values and predicted values of maximum chlorophyll-a in plankton samples. It may therefore be more appropriate to consider these values chlorophyll a equivalents, an estimate of total potential lake productivity.

An additional method was utilized to determine trophic status. The Trophic State Index (TSI) of Carlson (1977) was calculated from the mean summer Secchi disc transparency depth using the relationship:

Equation 4: $$TSI\ (SD) = 10\ \left(6 - \frac{Ln\ SD}{Ln\ 2}\right)$$

Where: TSI (SD) = trophic status based on summer Secchi disc transparency

Ln = natural log

This in turn can be related to chlorophyll a concentration (mg m^{-3}) using the relationship (Carlson, 1977):

Equation 5: $$Ln\ SD = 2.04 - 0.68\ Ln\ Chl\ a$$

Where: SD = Secchi disc transparency depth (m)

Chla = Chlorophyll a concentration (mg m^{-3})

As Secchi disc depth is an easily measured parameter, this provides the user with a fairly easy means of determining both the trophic state of the lake and the maximum chlorophyll-a concentration to be expected under such conditions.

The utility of both the Dillon model and Carlson's TSI is in the future management of the lake. Through these models, it will be possible to easily obtain a preliminary estimate of how changes in phosphorus loading will affect the trophic state of the lake, without the need to conduct a sampling program of the depth and scope of this study.